DOCUMENT RESUME

ED 372 950 SE 054 445

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TITLE	Exemplary Science and Mathematics Teachers.
INSTITUTION	Curtin Univ. of Tech., Perth (Australia). National Key Centre for Science and Mathematics.
REPORT NO	ISBN-0-908155-158
PUB DATE	89
NOTE	9p.
AVAILABLE FROM	Key Centre for Teaching and Research in School Science and Mathematics, Curtin University of Technology, GPO Box U1987, Perth, Western Australia 6001, Australia ($1 Australian).
PUB TYPE	Collected Works - Serials (022)
JOURNAL CIT	What Research Says to the Science and Mathematics Teacher; n1 Feb 1989
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Case Studies; Elementary Secondary Education; Foreign Countries; *Mathematics Instruction; *Mathematics Teachers; *Science Instruction; *Science Teachers; *Teaching Methods
IDENTIFIERS	Australia; *Exemplary Teachers

ABSTRACT

Teachers rarely get to see good teaching in the classes of others, usually because they are too busy in their own classrooms. The teaching practices of mathematics and science teachers recognized as good teachers in Western Australia were studied in the hope that other teachers might learn from these findings. Exemplary teachers (n=22) and a comparison group of non-exemplary teachers were observed and the students of these teachers completed questionnaires. This article discusses the patterns of behavior found among the exemplary teachers in the areas of: classroom management, emphasis on student understanding, favorable classroom learning environment, strong content knowledge, and encouraging student participation. (MKR)

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The Key Centre for School Science and Mathematics

What Research Says to the Science and Mathematics Teacher Number 1

curtin
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Perth, Western Australia

EXEMPLARY SCIENCE AND MATHEMATICS TEACHERS

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Barry J. Fraser and Kenneth Tobin

WHAT IS IT about educational research and educational policy reports that inevitably leads to conclusions that the quality of science and mathematics education needs to improve substantially? Is it the nature of educational research to highlight aspects of teaching and learning that must be improved? Or is it that researchers and report writers typically focus on what needs to be improved rather than what is already being done very well?

Some of the common pessimistic findings from past research are that classrooms are dominated by the teacher's lecturing and the use of textbooks, and that little attention is given to applications in daily life or to the development of higher-order thinking skills (Goodlad, 1984; Stake & Easley, 1978). Although there is little doubt that the findings of research in science and mathematics education can be depressing at times, it would be a serious mistake to assume that all research yields disappointing results. Quite on the contrary, the study described here provides a refreshing alternative to research which maligns science and mathematics education by focussing on outstanding examples of teaching.

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DESCRIPTION OF THE STUDY

OUR STUDY was known as the *Exemplary Practice in Science and Mathematics Education* study (Tobin & Fraser, 1987). Its focus was exemplary teaching and the positive facets of science and mathematics education. Because it was assumed that a great deal could be learned from the good things that teachers do, a study of exemplary science and mathematics teachers was undertaken to identify what it is that makes them so good.

It would be a serious mistake to assume that all research yields disappointing results.

Teachers rarely get to see good teaching in the classes of others, often because they are too busy in their own classrooms. So, we studied the teaching practices of teachers who were recognized as good teachers, in the hope that we would be able to describe what they did and that other teachers might learn from their classroom practices.

The inspiration for the *Exemplary Practice in Science and Mathematics*

Education project grew out of a project entitled the *Search for Excellence* (Penick & Yager, 1983), based at the University of Iowa and sponsored by the National Science Teachers Association and other organizations in the USA. The rationale for the American project was that a focus on successful science programs holds hopes for improving practice. The obvious enthusiasm, optimism and excitement generated by the *Search for Excellence* encouraged a research team based at Curtin University to embark on a similar study in Western Australia.

This research on exemplary practice involved a total of 13 researchers from Curtin and other institutions in Perth. The study focused on 22 exemplary teachers and a comparison group of non-exemplary teachers. Of these 22 teachers, seven taught mathematics (two secondary and five primary), six taught senior-school biology, chemistry or physics, four taught junior secondary science and five taught primary science. Seven of the exemplary teachers were women.

The exemplary teachers were identified by asking other teachers, Ministry of Education advisory staff and tertiary institution staff to nominate teachers whom they considered to be outstanding. We did not provide our own definition of "outstanding", nor did we ask these people to spell out the criteria they used in making their nominations. Teachers were only selected for the study if they had been nominated as outstanding by several different people.

The *Search for Excellence* in the USA had a focus on exemplary programs and involved the study, evaluation and dissemination of program descriptions. In contrast, the focus in the Western Australian study was on the classroom practices employed by exemplary teachers. Consequently, the Australian researchers carried out intensive classroom observation of exemplary teaching and interviewed teachers and students. Altogether, the researchers were involved in over 500 hours of classroom observation. The researchers took field notes during their classroom visits and these were discussed, analysed and interpreted during regular meetings of the research team. In addition, students completed questionnaires to provide their opinions about their classroom environments.

FINDINGS

IN SOME RESPECTS, the most valuable contributions of this study are the eleven detailed case studies of exemplary teachers of science and mathematics at various grade levels. In addition, the findings from the individual case studies have been synthesized to identify characteristics common to all of the exemplary teachers. Although not all of the exemplary teachers taught in the same way, nevertheless some patterns of behaviour were common to all exemplary teachers, irrespective of the subject or grade level taught. Consequently, emphasis on these behaviours is likely to improve other teachers' teaching. Some of these characteristics are discussed below.

Classroom Management

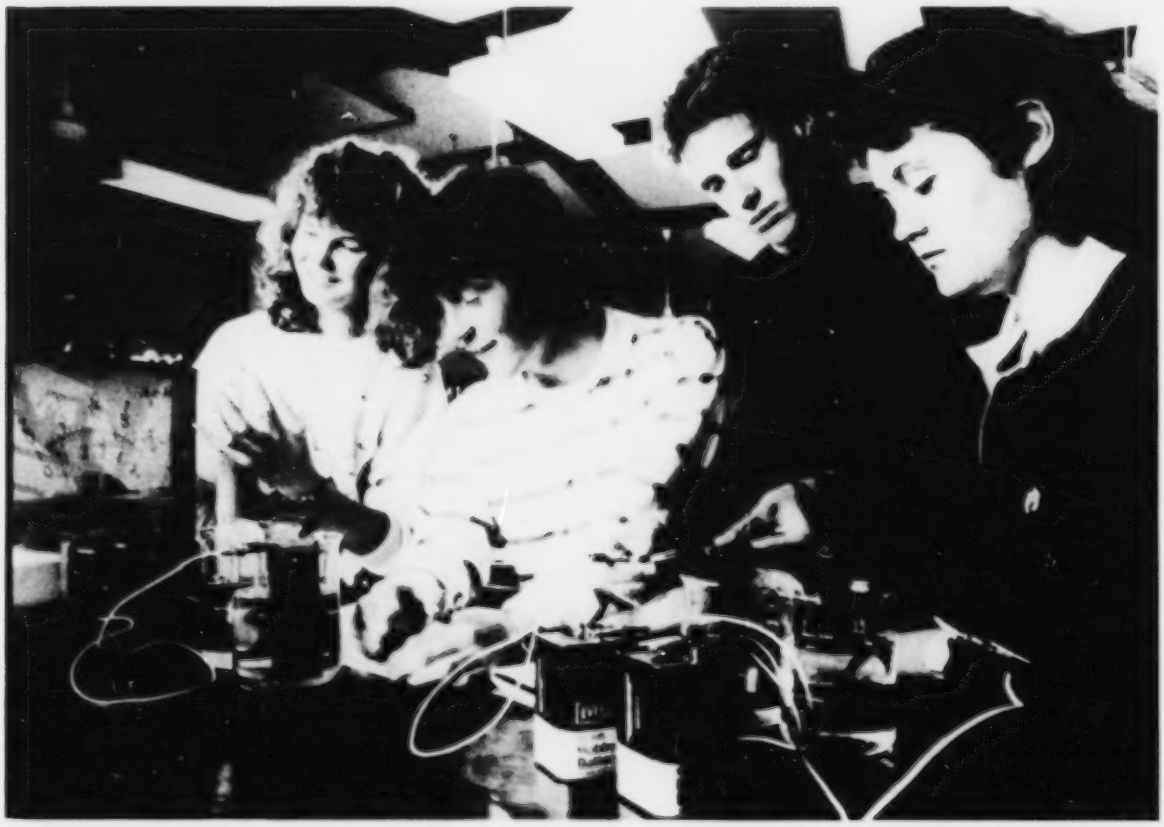
A common feature of exemplary science and mathematics teachers was that they managed their classrooms effectively. The teachers actively monitored student behaviour in their classes by moving around the room and speaking with individuals from time to time. Also they maintained control-at-a-distance over the entire class. Little evidence of student misbehaviour was noted.

Students were able to work independently and cooperatively in groups.

The teachers had time to consider what to do next and to reflect on the lesson as it progressed.

Interestingly, many of the teachers listed the development of autonomy and independence among their goals. Because students understood the rules and worked within them , there was no need for the teacher to devote much time at all to handling student behaviour problems. Students knew what to do, because teachers communicated expectations clearly, and appeared to enjoy working in the classroom. Of course, it is likely that teachers had established clear classroom rules prior to the researchers' observations.

In order for teachers to be able to monitor understanding successfully, it is necessary for students to be well-behaved and cooperative. Although the exemplary teachers in our study usually did not have the easiest classes in their schools, still they appeared able to mange student behaviour easily. In most classes taught by exemplary science and mathematics teachers, students demonstrated a capacity to work together if problems arose, to seek help from a peer or to wait for the teacher to provide assistance. Consequently, teachers were not under pressure to maintain order, nor were they rushing from one student to another at the request of students experiencing difficulties. Rather, the teachers had time to consider what to do next and to reflect on the lesson as it progressed. Most exemplary teachers appeared to monitor student engagement and understanding in a thoughtful, systematic and routine manner.



For example, we observed one of the exemplary mathematics teachers exhibiting fine management skills. Through a blend of encouragement and firmness, the teacher communicated her expectations of pupil behaviour. Although she allowed students to chat a little during individualized and small-group activities, students were not permitted to talk or move about during whole-class work. This teacher also insisted that only one student spoke at a time during class discussions.

Emphasis on Student Understanding

Most exemplary teachers in our study used strategies aimed at assisting students to learn with understanding. All exemplary teachers provided activities in which students could get involvemed. In primary school grades, the activities were based on the use of materials to solve problems and, at the high school level, teachers often used concrete examples for abstract concepts. The key to teaching with understanding was the verbal interaction which enabled teachers to monitor student understanding of science and mathematics concepts.

The exemplary science and mathematics teachers were effective in a range of verbal strategies, including asking questions to stimulate thinking, probing student responses for clarification and elaboration, and providing explanations which gave students additional information. For example, in one of our case studies involving three exemplary primary science teachers, a materials-centred and problem-solving emphasis allowed students to make and test predictions, students were encouraged to discuss their findings with their classmates and the teacher, and the teachers' questions in a small-group and whole-class activities were of high quality. The teachers knew which questions to ask in order to facilitate important understandings about science.

Similarly, exemplary high school teachers provided activities which promoted understanding. For example, an exemplary biology teacher emphasized inquiry rather than verification of facts and principles, and was a model inquiry teacher, not only in the way that he asked questions but also in the way that he encouraged students to think for themselves and to ask questions.

An exemplary Year 6 mathematics teacher in our study emphasized problem-solving rather than merely getting the right answer. She believed that students learn by doing and, so, manipulative materials were commonly used by the teacher and were readily available for students to use during small-group and individualized activities. This teacher constantly monitored students' involvement and understanding and provided relevant feedback.

Favourable Classroom Learning Environment

In addition to the information collected by observation and interview, questionnaires were administered to find out what students thought about

Students perceived their classroom climate as conducive to learning .

the learning environments (Fraser, 1986) of classes taught by exemplary teachers and those taught by a comparison group of non-exemplary teachers. These instruments provided some quantified information about exemplary teachers' classrooms and helped us to see classrooms through the students' eyes.

All of the case studies indicated that students of exemplary teachers perceived their classroom environments as being good places for learning. For example, both classes of an exemplary biology teacher perceived their actual classroom climate considerably more favourably than the way that students taught by non-exemplary teachers viewed their science classes.

The biggest differences occurred for involvement (the extent to which students participate and show interest in class activities), teacher support (the extent to which the teacher helps, befriends and is interested in the students) and order and organization (the extent to which classroom activities run smoothly, and students behave in an orderly way). In addition, in classes taught by exemplary teachers, there was a surprising similarity between the kind of classroom environment that students would like and the classroom environment which they were actually in.

Strong Content Knowledge

The research highlighted numerous times the importance of the teacher's content knowledge. In most of the lessons which we observed, exemplary teachers displayed strong knowledge of their content area, and this enhanced their teaching. But the importance of content knowledge also was illustrated in a negative sense with one of our exemplary teachers. In one case study, an exemplary secondary school teacher made several errors while teaching a general science topic which was out of his field. The net result of the teacher's lack of content knowledge was an emphasis on learning of facts and the development of misconceptions. Moreover, these instances of teachers having less than optimal backgrounds in the content to be taught occurred in classes of teachers who had been nominated as exemplary. Such problems are likely to be of greater significance in the classes of non-exemplary teachers.

The research highlighted the importance of teachers' content knowledge.

Encouraging Student Participation

Another common characteristic of exemplary teachers' classes was the encouragement given to all students to be actively involved in classroom discussions and activities. By avoiding sarcasm or ridicule, teachers made it "safe" for students to "have a go" at answering questions or doing activities.

For example, we observed that one of the exemplary mathematics teachers moved from one student to another during individualized work to provide assistance. The physical distance between student and teacher was small and the teacher spoke softly. Consequently, conversations were fairly private and did not disrupt the rest of the class. This technique convinced students that even the most trivial questions would be received in a sympathetic and caring manner and would not be publicized to the whole class. Furthermore, the rest of the students in the class benefitted by not having their concentration broken.

CONCLUSIONS

WHAT WAS LEARNED from the case studies of exemplary practice was not all that surprising, nor did it provide grounds for total optimism. The exemplary teachers managed their classes well, taught with student understanding as a focus, encouraged students to participate actively, and maintained classroom environments that were con-

ducive to learning. As well, they had a sound grasp of the content that students were to learn. Because no one of these factors alone was sufficient for effective teaching, the study highlights the complex nature of teaching and learning. Clearly, effective teaching requires much more than presenting content from textbooks. Consequently, preservice and continuing teacher education have an important role to play in helping teachers develop some of the teaching skills that are found in exemplary teachers' classes.

In order to promote student understanding, exemplary teachers' questions were used skillfully to focus student engagement and to probe for misunderstandings. When explanations were given, they were clear and appropriate. Concrete examples often were used to illustrate abstract concepts and analogies and examples from outside the classroom were used frequently to facilitate understanding. In addition, teachers appeared to anticipate areas of content likely to provide students with problems. At the conclusion of a lesson, the main points were highlighted and revised prior to the close of the lesson.

Quite clearly, exemplary teachers had extensive knowledge of how students learned as well as what to teach and how best to teach it. The findings are a salient reminder that teaching is a demanding profession. Without both the necessary content and pedagogical knowledge, teachers can expect to flounder. And those who are experiencing difficulties can anticipate continuing problems unless they attain mastery over what they are teaching and how to teach it.

Even in a study of exemplary teachers, weaknesses in content knowledge were found to cause problems. Therefore, administrators should be loathe to schedule teachers for out-of-field teaching assignments. Willing and dedicated teachers can expect to experience

considerable problems if they are required to teach in areas in which they have inadequate content knowledge. Often it is felt that there are few alternatives because suitably qualified science and mathematics teachers are in short supply. But it should be recognized that the apparently common practice of meeting needs within a school by having teachers teach outside their main fields creates problems for students.

The main implication for teacher educators is that there is a need to identify the discipline-specific knowledge required by science and mathematics teachers, and to help them to acquire this knowledge in a form that can be used in the classroom. Furthermore, there is much to be learned from exemplary science teachers which can be of benefit to others. Perhaps the most fruitful area relates to the activities and strategies used to teach specific areas of science content. Detailed case studies

The findings are a salient reminder that teaching is a demanding profession.

which describe activities in terms of teacher and student involvement in learning tasks can serve as the content of science and mathematics teacher education courses. For example, case studies would provide descriptions of hands-on activities, examples of key questions asked by the teacher to stimulate thinking, and a variety of student responses which indicate complete understanding, partial understanding, and misunderstanding of specific concepts. Classroom researchers and teacher educators should work together with exemplary teachers to begin the task of creating a case history for science and mathematics education.

The *Exemplary Practice in Science and Mathematics Education* study suggested some models of teaching which all science and mathematics teachers can adopt. In this sense, the study provides grounds for optimism about the future of science and mathematics education. In addition, the analysis of exemplary teaching revealed an Achilles heel which needs the close attention of all science and mathematics educators. Additional resources are probably needed to assist teachers to obtain the knowledge needed to teach specific science and mathematics content. Provision of these resources to all science and mathematics teachers, as well as convincing them that knowledge limitations might be inhibiting their teaching effectiveness, represent substantial problems for all educators of science and mathematics teachers.

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FURTHER INFORMATION ABOUT EXEMPLARY PRACTICE STUDY

Do you want to find out more about the *Exemplary Practice in Science and Mathematics Education* study? If so, you might want to obtain the 227-page book entitled *Exemplary Practice in Science and Mathematics Education* edited by Ken Tobin and Barry Fraser. This book contains eleven case studies of exemplary science or mathematics teaching, together with the editors' chapters devoted to an introduction, the results obtained from the classroom environment questionnaires and a conclusion. The book also contains a foreword by Professor James J. Gallagher of Michigan State University.

To obtain a postage-free copy of the book *Exemplary Practice in Science and Mathematics Education* send a cheque for $20 made payable to "Key Centre for School Science and Mathematics" to Key Centre for School Science and Mathematics, Applied Science Building, Curtin University of Technology, GPO Box U1987, Perth, Western Australia 6001.

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ISBN 0 908155 158